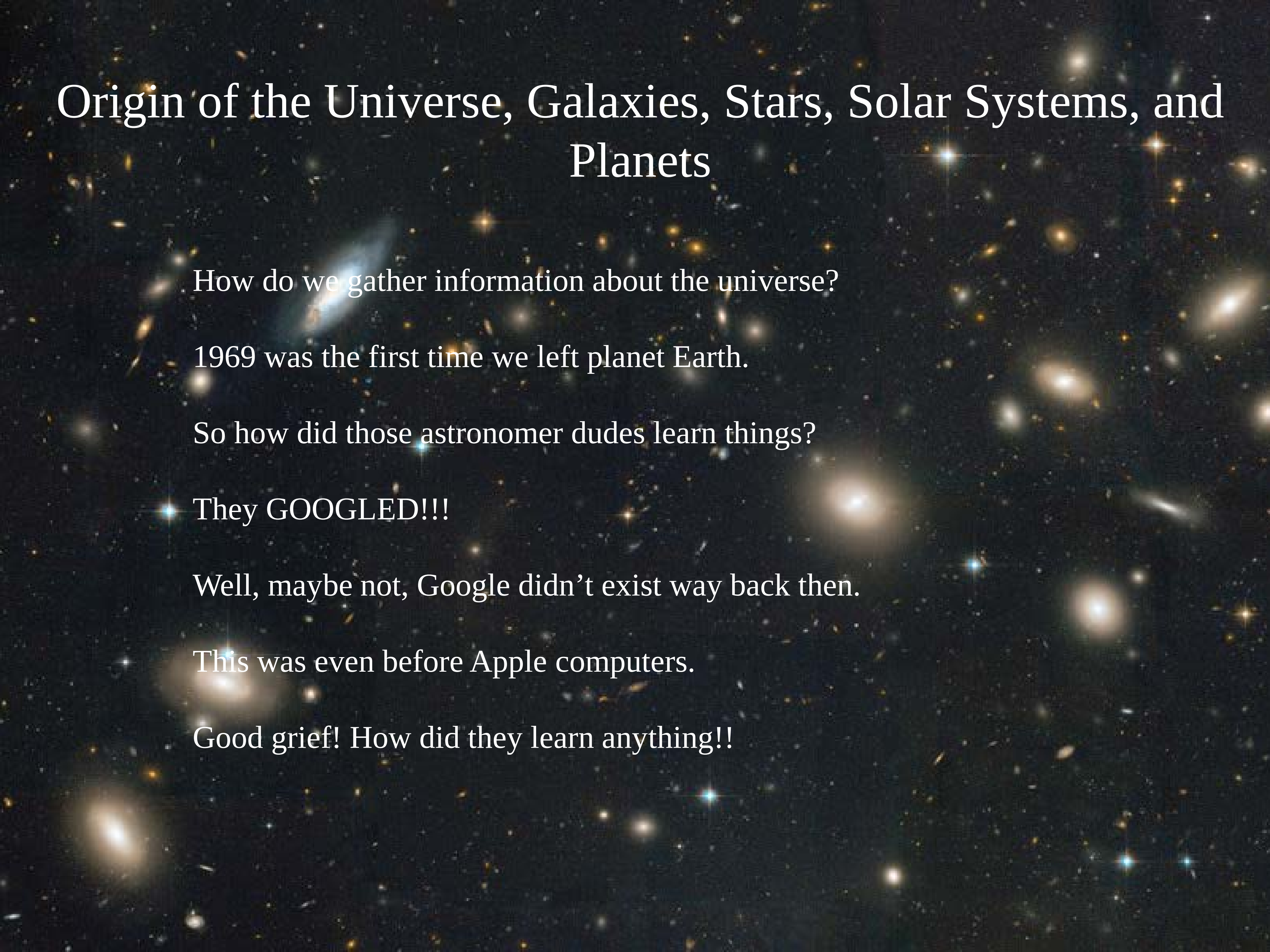
Origin of the Universe, Galaxies, Stars, Solar Systems, and Planets



How do we gather information about the universe?

1969 was the first time we left planet Earth.

So how did those astronomer dudes learn things?

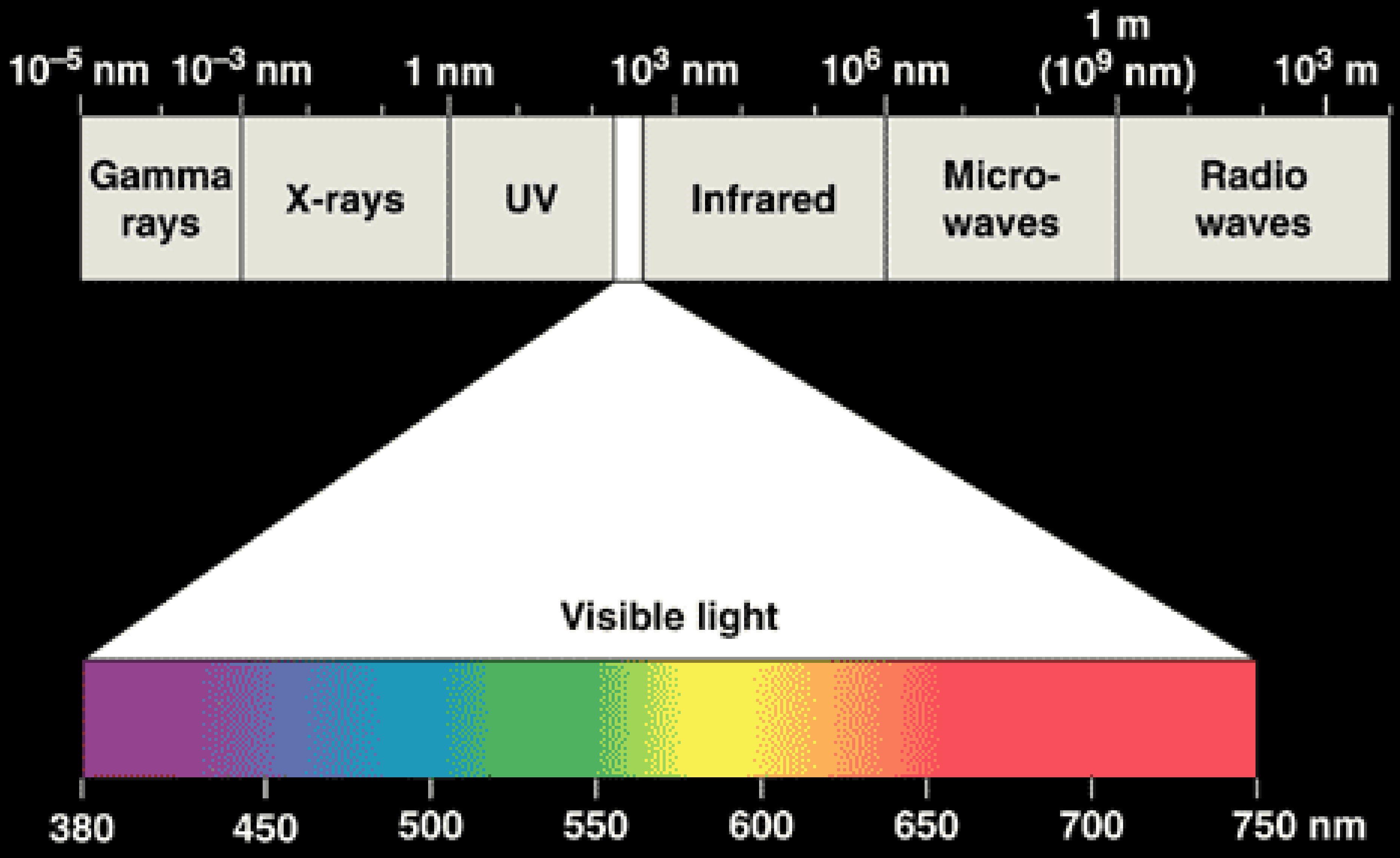
They GOOGLED!!!

Well, maybe not, Google didn’t exist way back then.

This was even before Apple computers.

Good grief! How did they learn anything!!

Telescopes

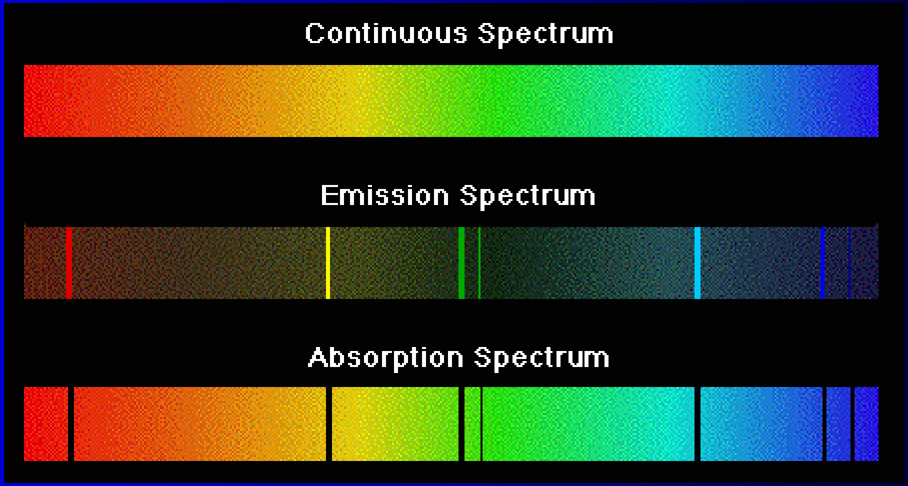


Shorter wavelength → Longer wavelength

Higher energy → Lower energy

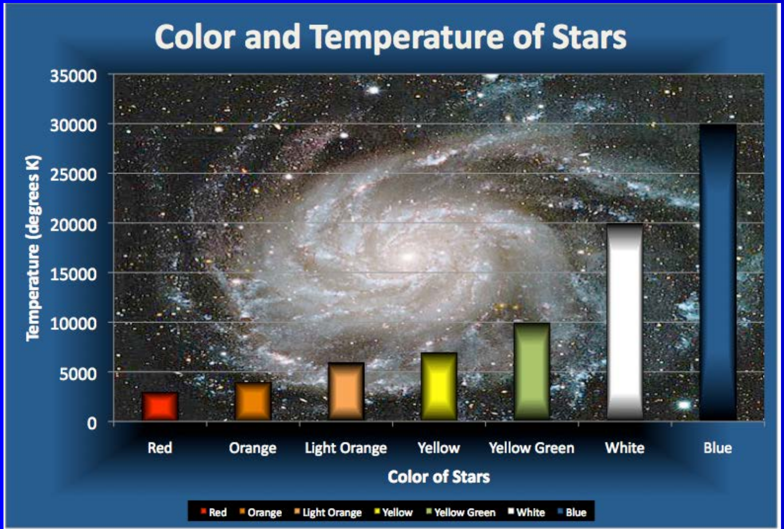
Types of Spectra

- Continuous
- Emission
- Absorption



We can use the different types of spectra to

- Determine the temperature of galaxies and stars
- Determine the chemical composition of galaxies and stars
- Determine the velocity of approach or recession of stellar objects



Perfect Radiators and the Continuous Spectrum

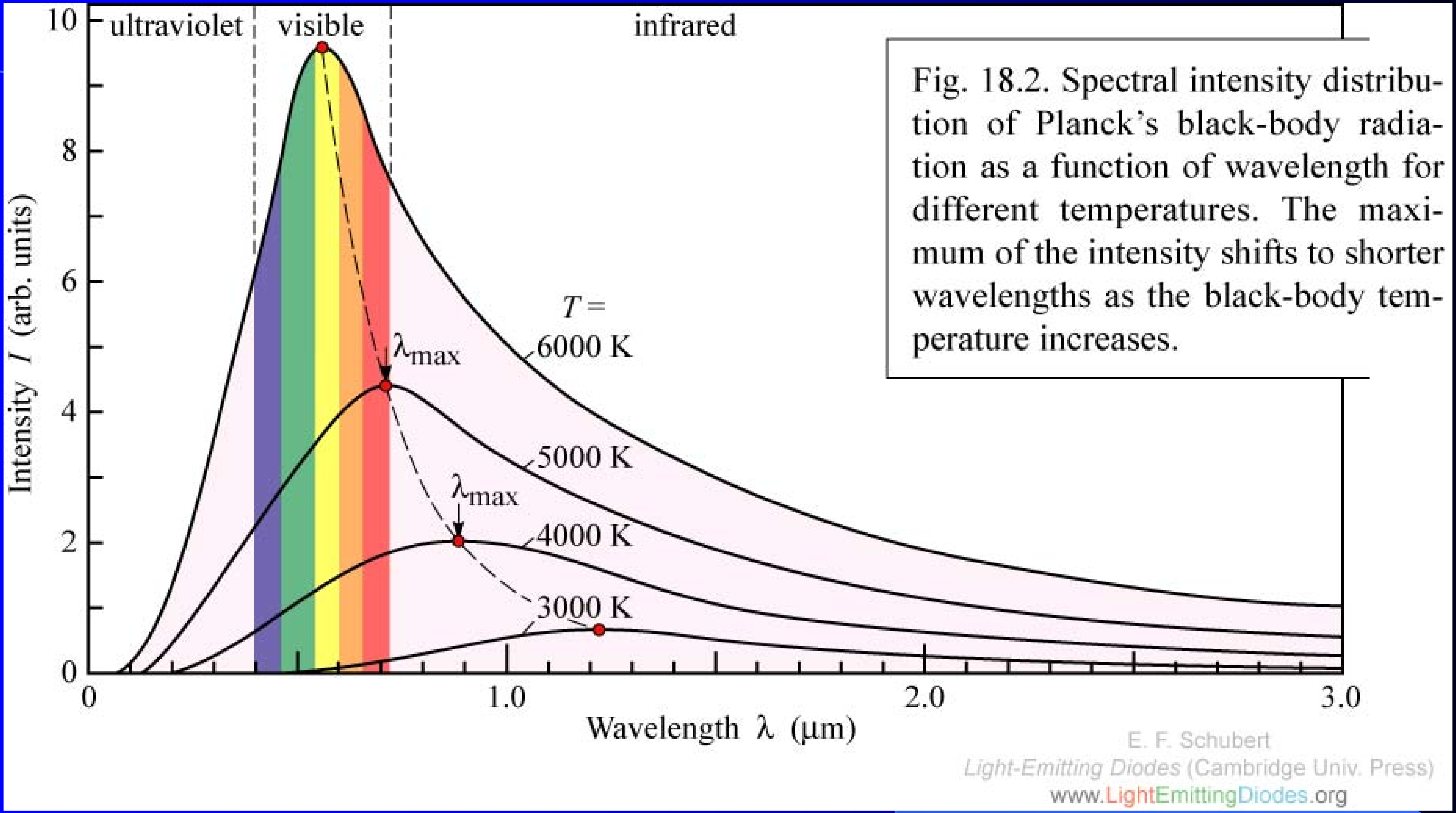


Fig. 18.2. Spectral intensity distribution of Planck's black-body radiation as a function of wavelength for different temperatures. The maximum of the intensity shifts to shorter wavelengths as the black-body temperature increases.

E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

Equations describing *Perfect Radiators (Black bodies)*

Stefan-Boltzmann Law: $E = \sigma T^4$

E = total energy radiated per unit area of a black body

$\sigma = 5.670400 \times 10^{-8}\ \mathrm{J\ s^{-1}\ m^{-2}\ K^{-4}} = 5.6704 \times 10^{-5}\ \mathrm{J\ s^{-1}\ m^{-2}\ K^{-4}}$

T = Temperature (in K)

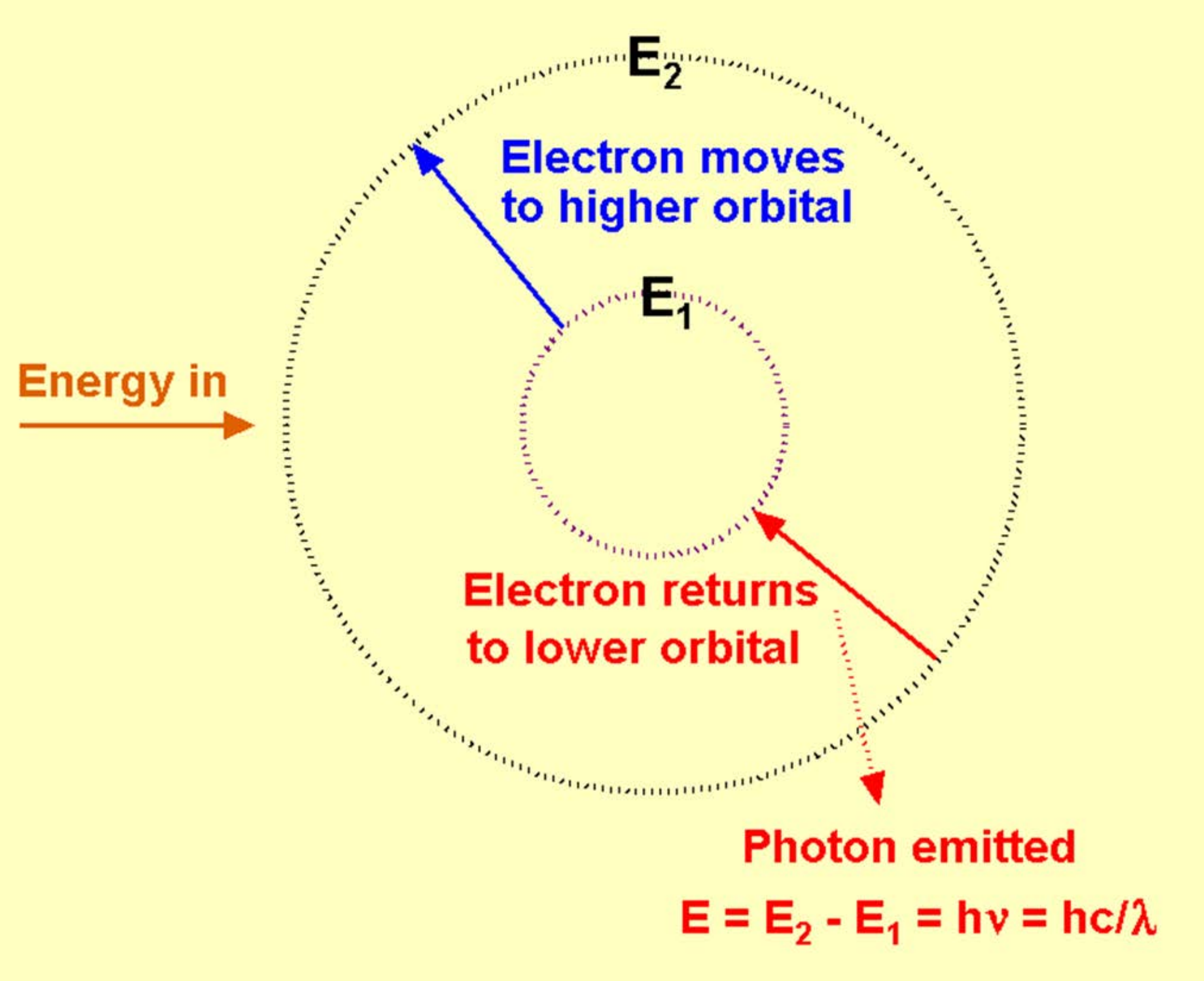
Wien's Displacement Law : $\lambda_{max} = b/T$

λ_{max} = wavelength of the peak of the emission of a black body

$b = 2.8977685 \times 10^{-3}$ m K = 2,897,768 nm K = 2900 μm K

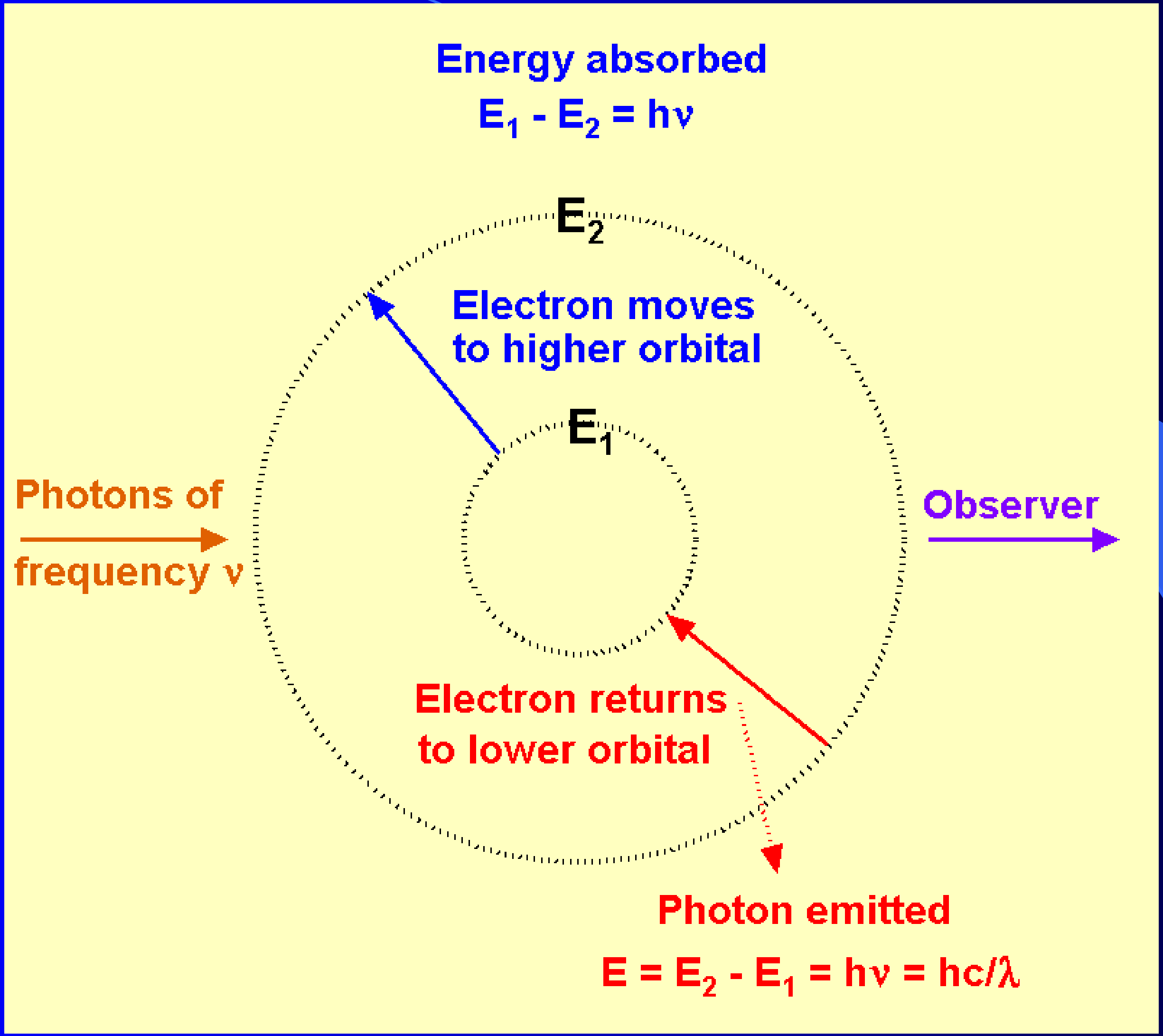
T = Temperature (in K)

Emission spectrum



$E = E_2 - E_1 = h\nu = hc/\lambda$

Absorption spectrum



Energy absorbed

$E_1 - E_2 = h\nu$

Electron moves to higher orbital

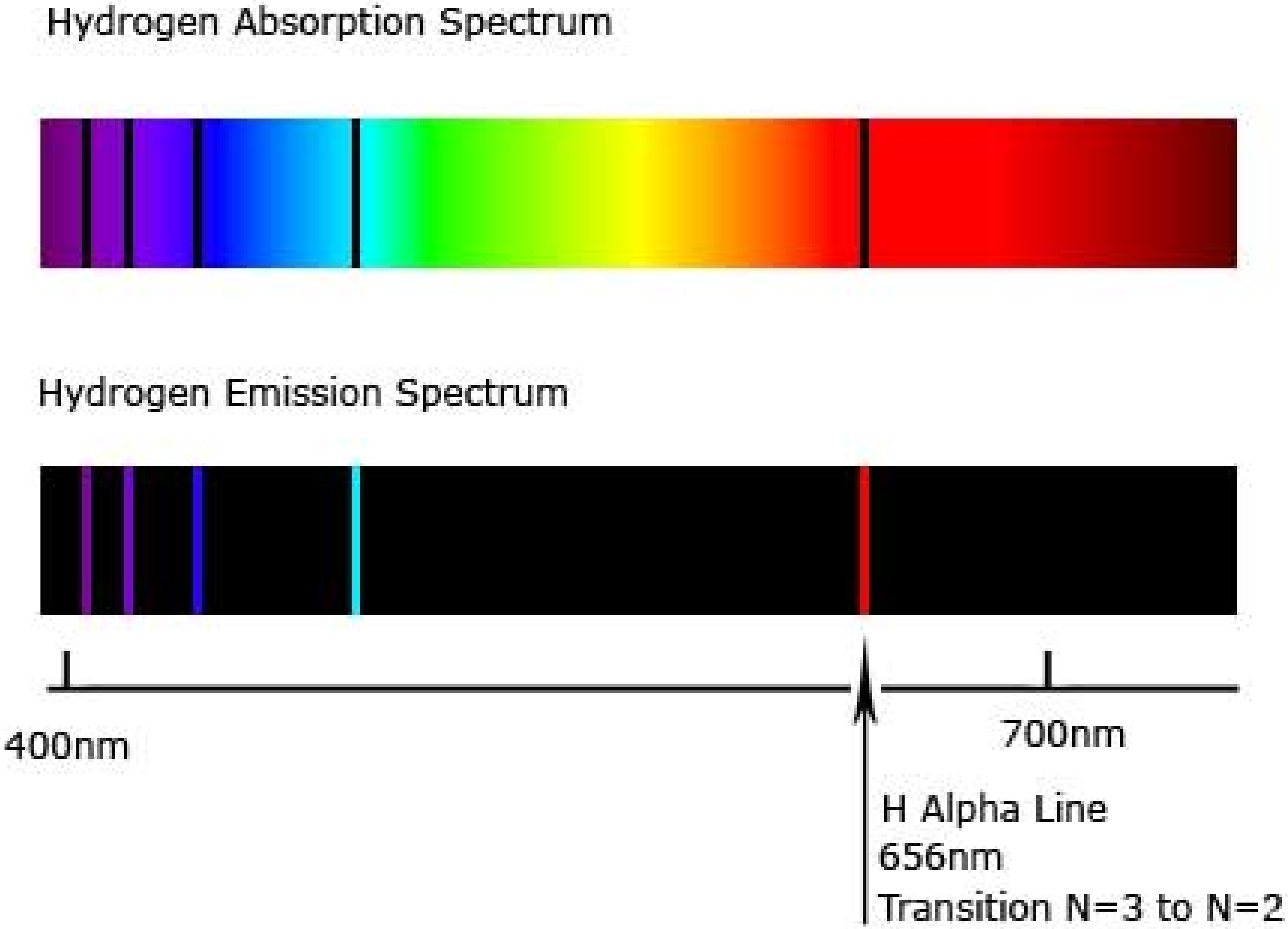
Photons of frequency ν

Observer

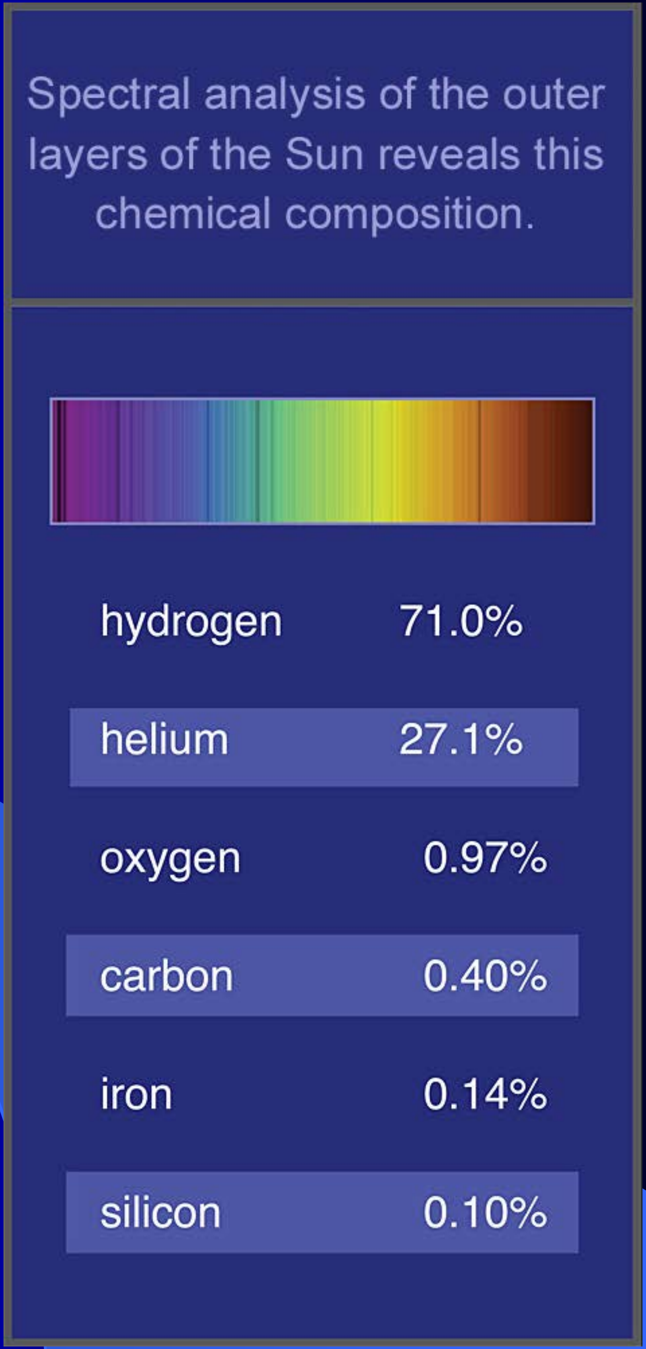
Electron returns to lower orbital

Photon emitted

$E = E_2 - E_1 = h\nu = hc/\lambda$

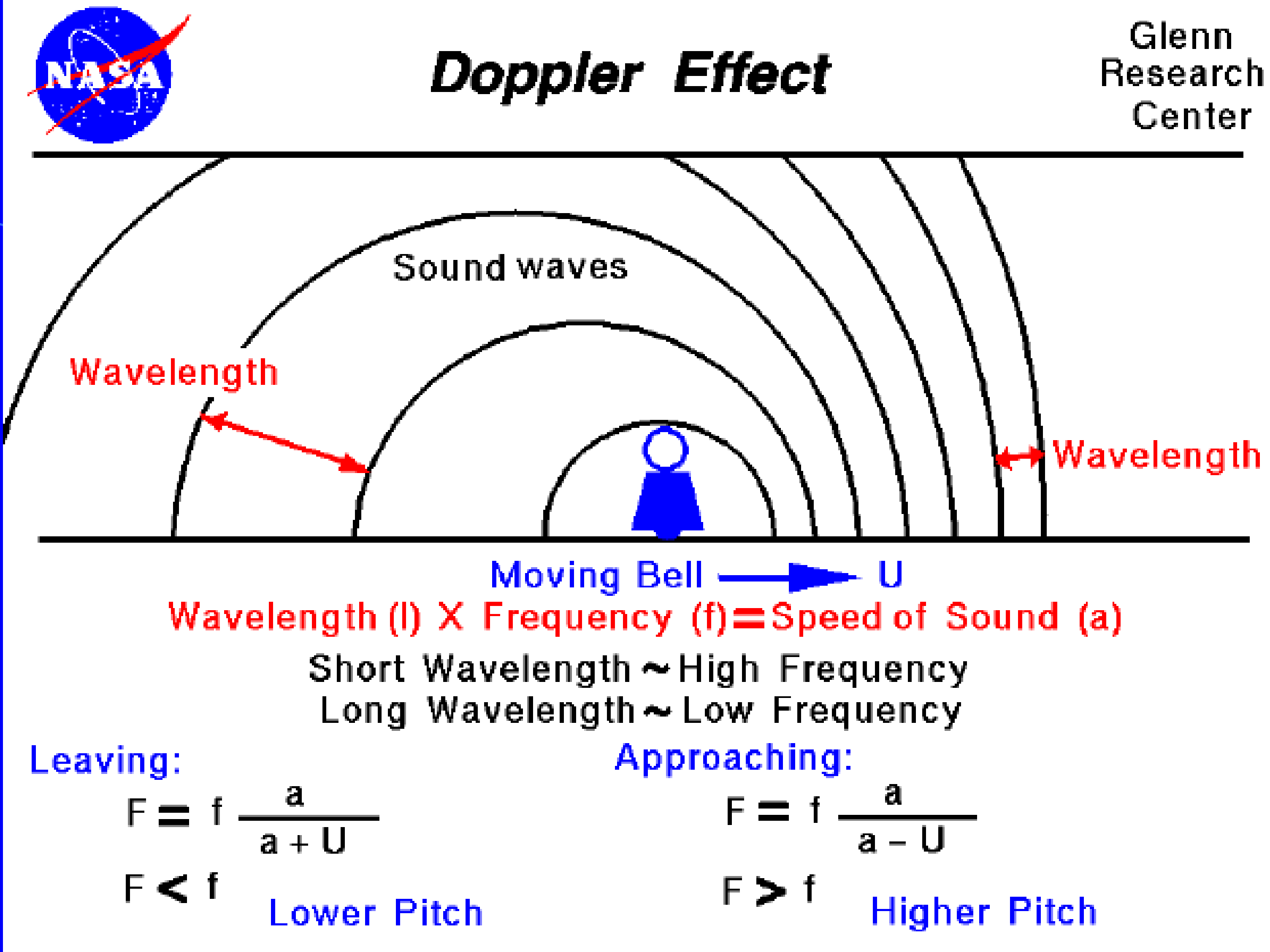

Hydrogen Absorption Spectrum
Hydrogen Emission Spectrum
400nm
700nm
H Alpha Line
656nm
Transition N=3 to N=2

Absorption spectrum for the outer layers of the sun. The dark lines are the absorption bands. The wavelengths (energies) correspond to specific electronic transitions within atoms. These observations can be used to determine the chemistry of the sun.



Spectral analysis of the outer layers of the Sun reveals this chemical composition.

hydrogen	71.0%
helium	27.1%
oxygen	0.97%
carbon	0.40%
iron	0.14%
silicon	0.10%



Doppler Effect

Glenn
Research
Center

Wavelength (l) X Frequency (f) = Speed of Sound (a)

Short Wavelength ~ High Frequency
Long Wavelength ~ Low Frequency

Leaving:

$$F = f \frac{a}{a + U}$$

$F < f$ Lower Pitch

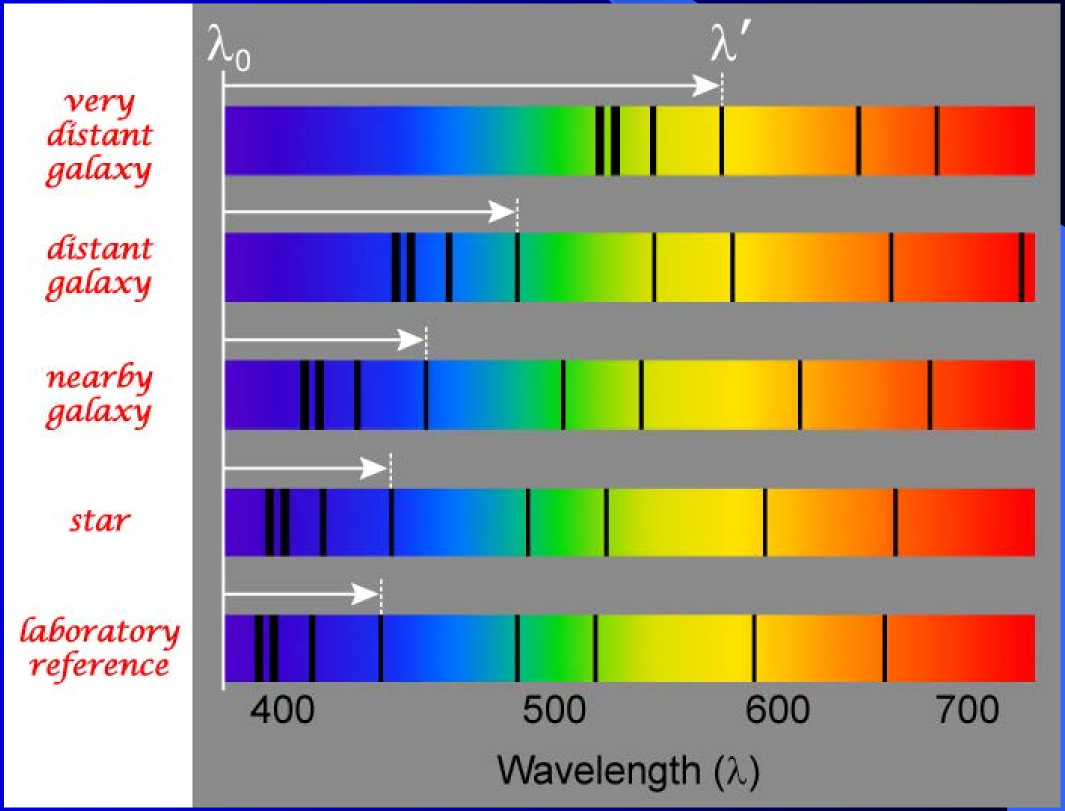
Approaching:

$$F = f \frac{a}{a - U}$$

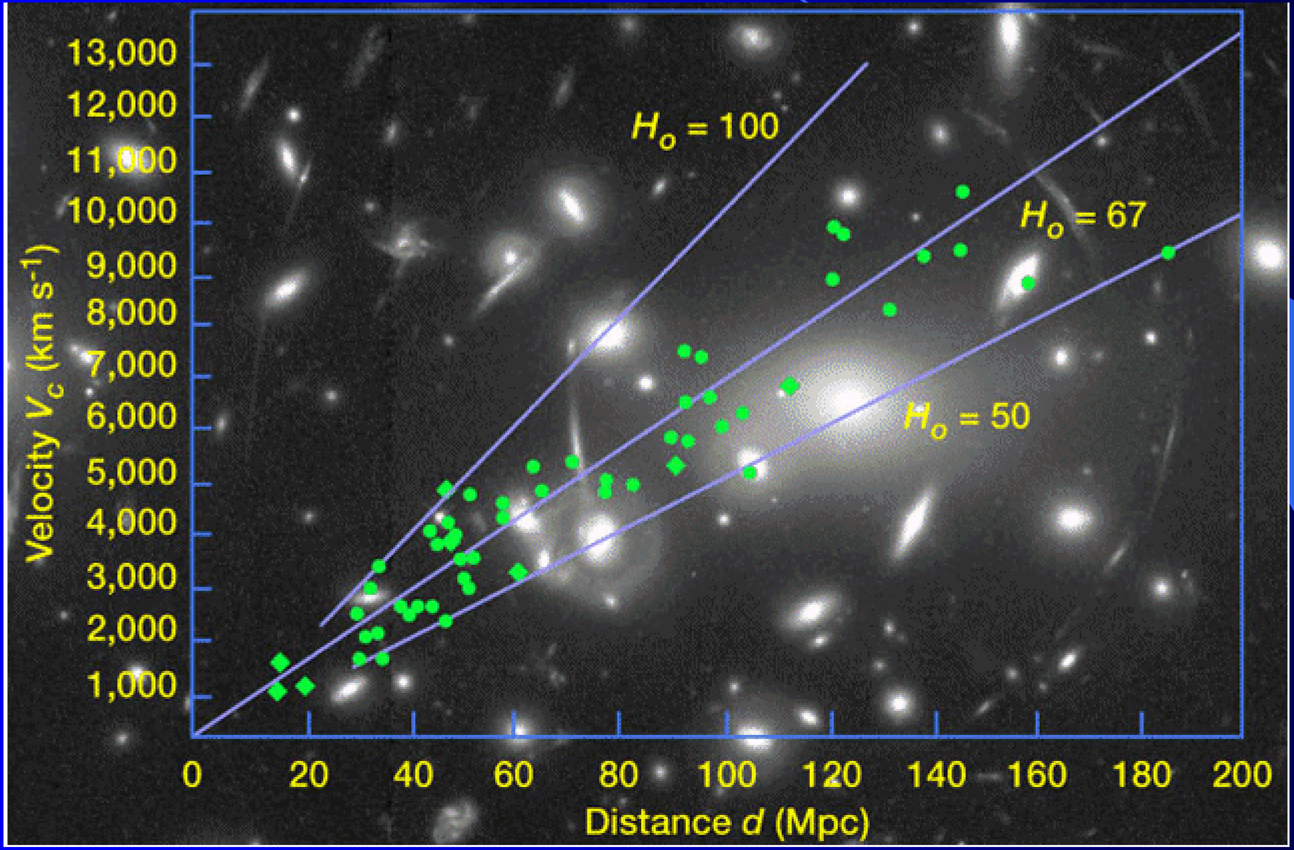
$F > f$ Higher Pitch

Doppler shifts

- If the distance between two objects is constant the spectra don’t change.
- If the object is receding the spectra shift to longer wavelengths (red shift).
- If the object is approaching the spectra shift to shorter wavelengths (blue shift).
- The greater the shift, the greater the velocity of approach or recession.
- For stellar objects, the observation is that more distant objects have greater shifts than nearer objects.
- The velocity of recession increases with distance.

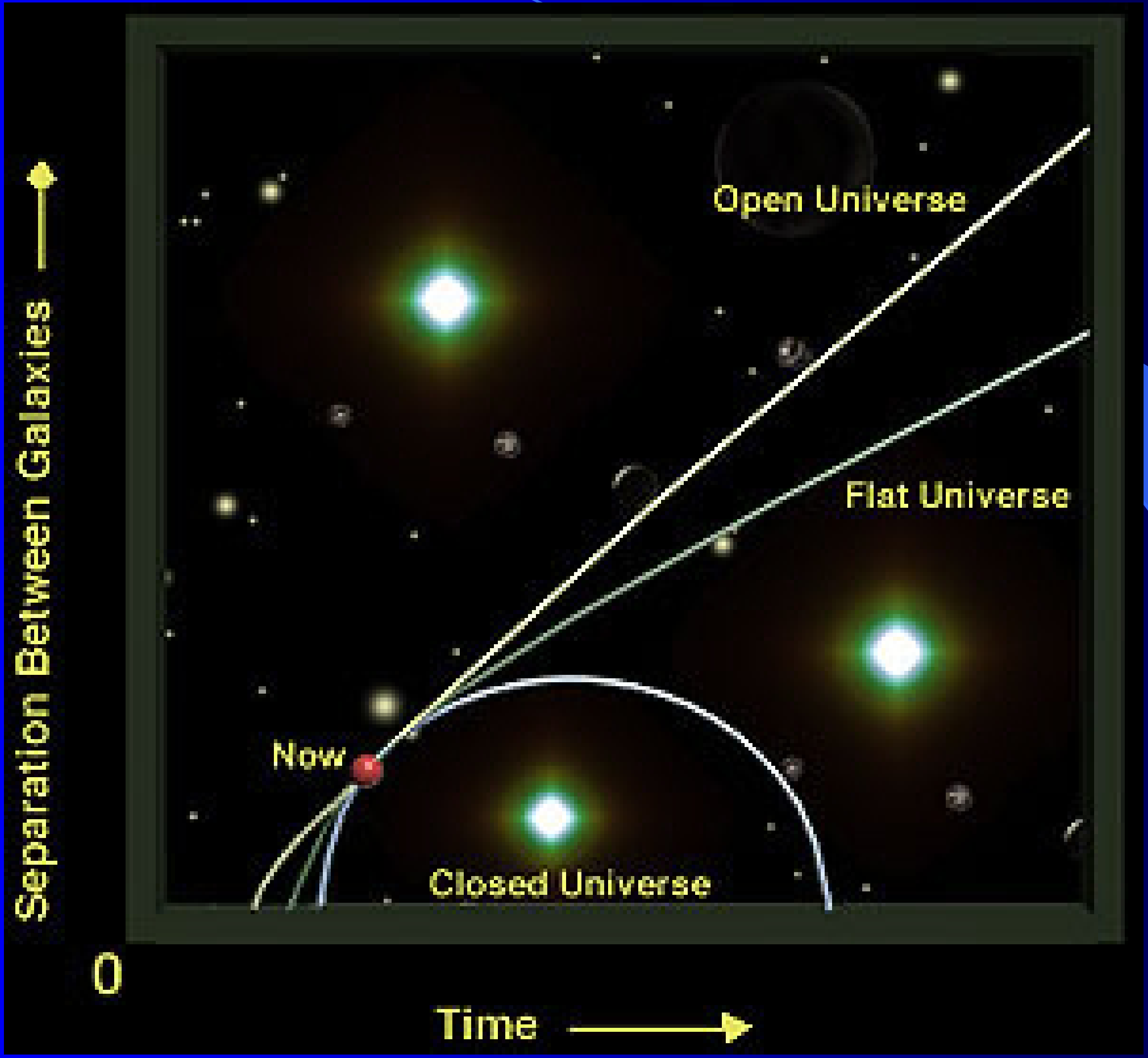


The relationship between distance and the velocity of recession is known as the Hubble Constant

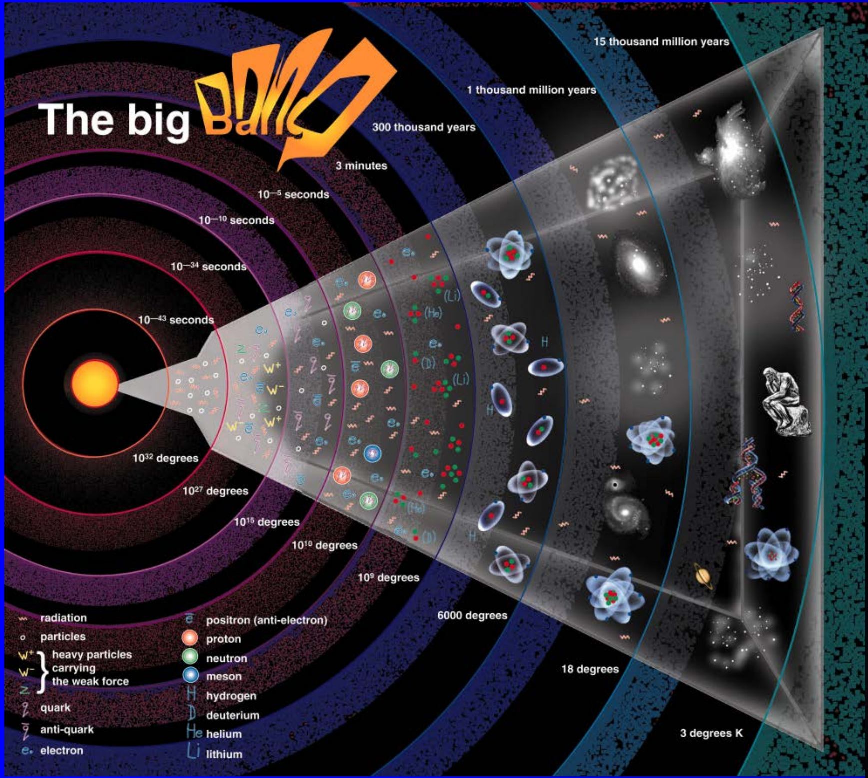


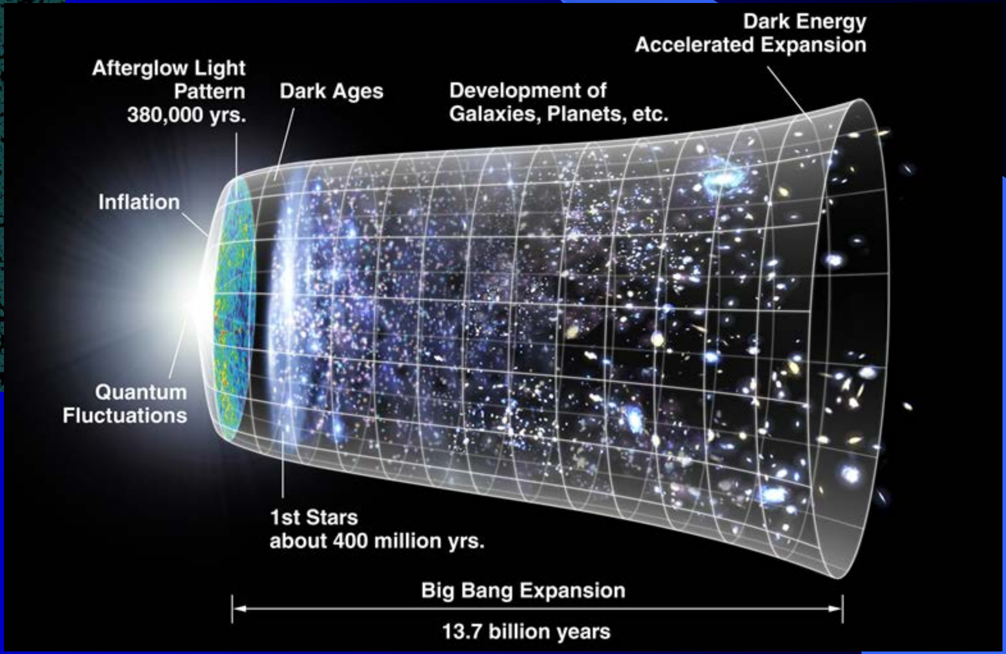
Hubble Constant (H_o) = km/s/3.2 x 10^6 ly

Is the Universe Open or Closed?



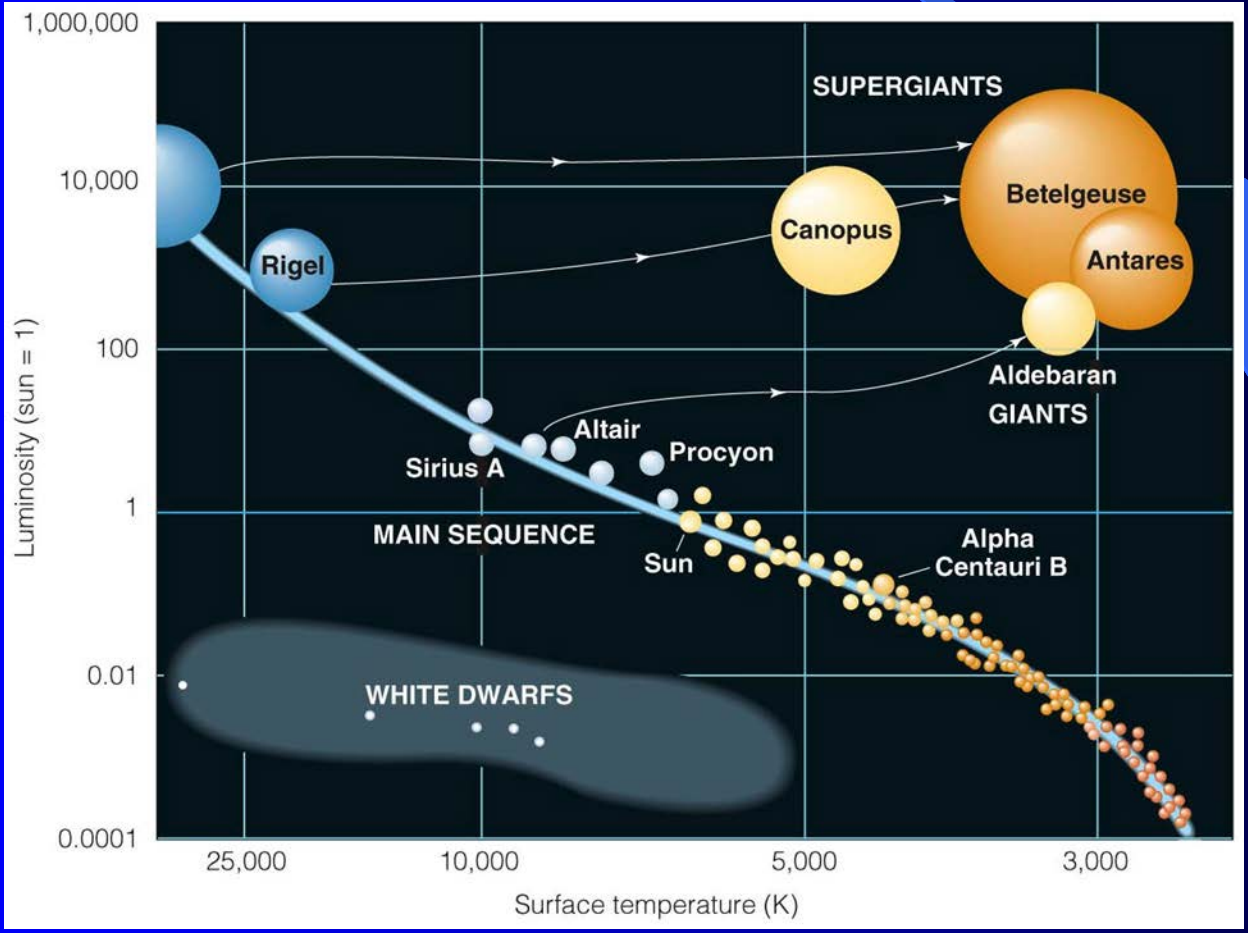
The “Big Bang”


The big Bang
15 thousand million years
1 thousand million years
300 thousand years
3 minutes
10^{-5} seconds
10^{-10} seconds
10^{-34} seconds
10^{-43} seconds
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
18 degrees
3 degrees K
radiation
particles
W^+ W^- Z heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
H hydrogen
D deuterium
He helium
Li lithium


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

Stars – Classification and Formation

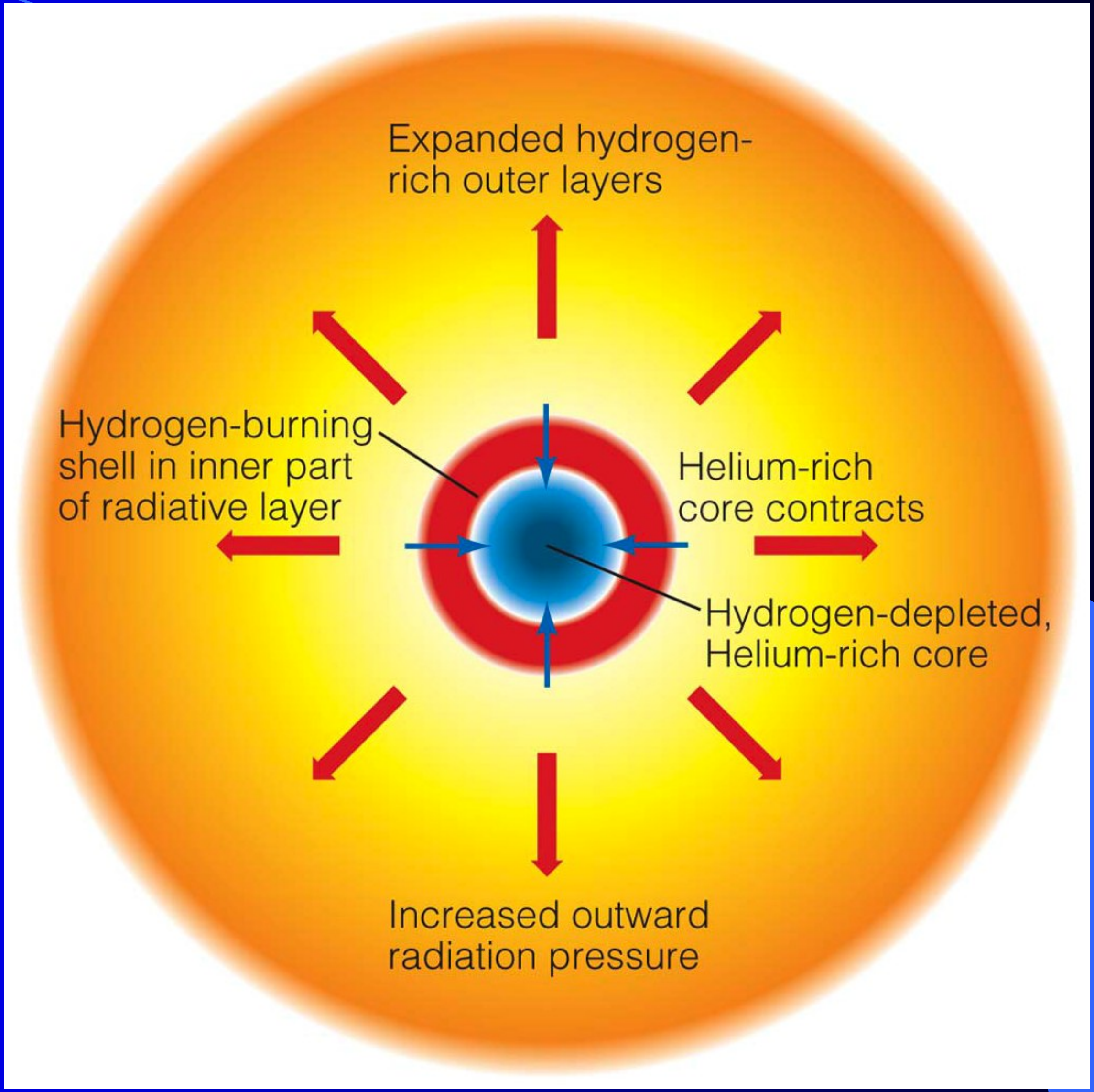
- Stars are classified by color and brightness
  - Color is an indication of temperature
  - brightness is a function of both the star's luminosity (energy emitted) and its distance from the Earth



Life history of a star

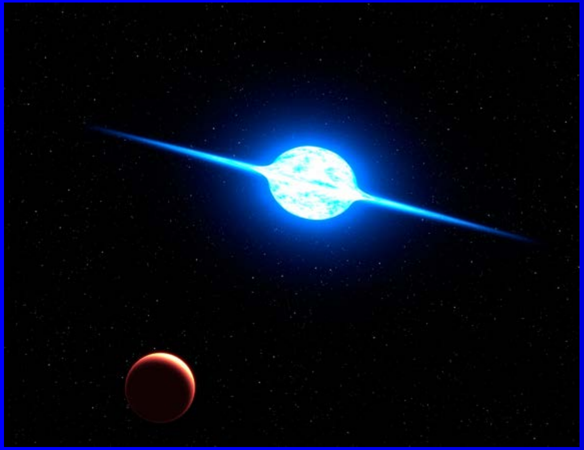
- Main sequence
- White dwarf
- Black dwarf
- In special cases – neutron star or black hole

When the star leaves the main sequence at the end of the fusion reactions a variety of processes occur, referred to as r, s, and p, which form the elements in the periodic table with atomic numbers greater than 26 (Fe).

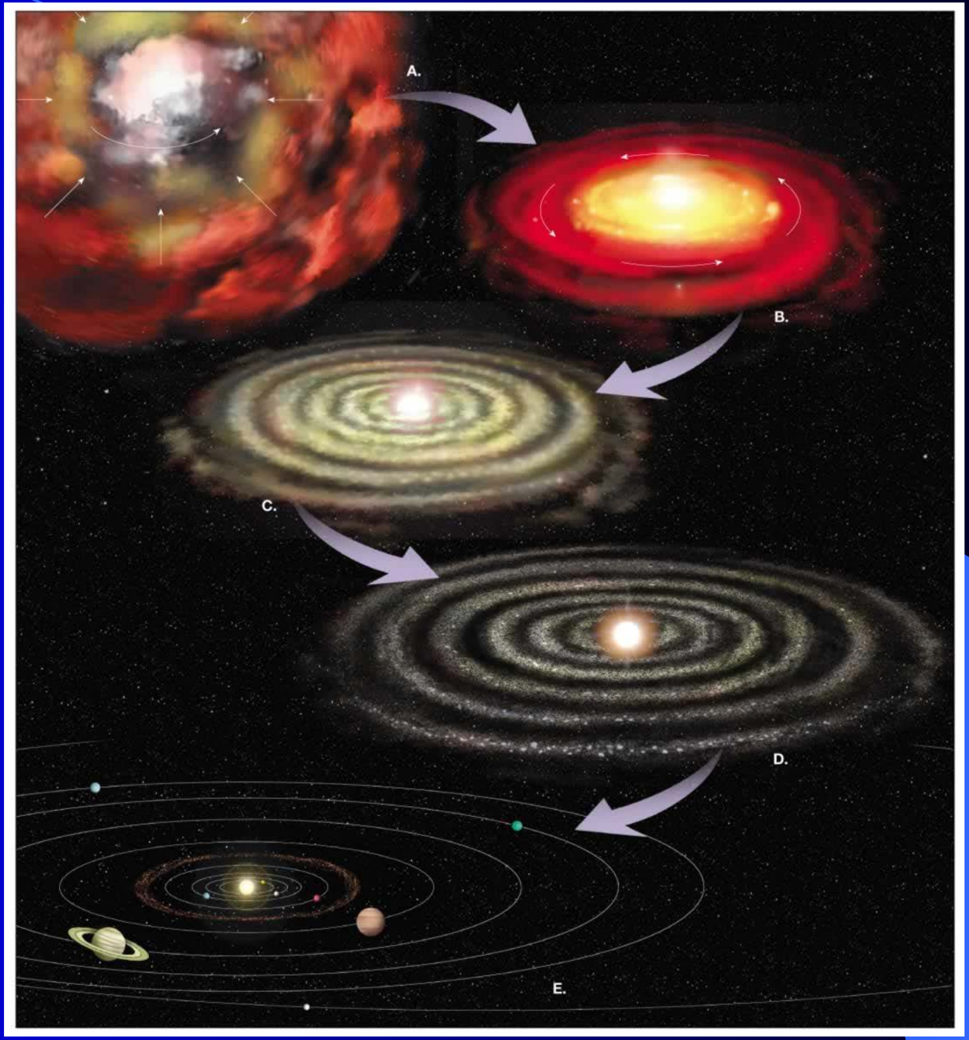


Formation of the Solar System

Nebula



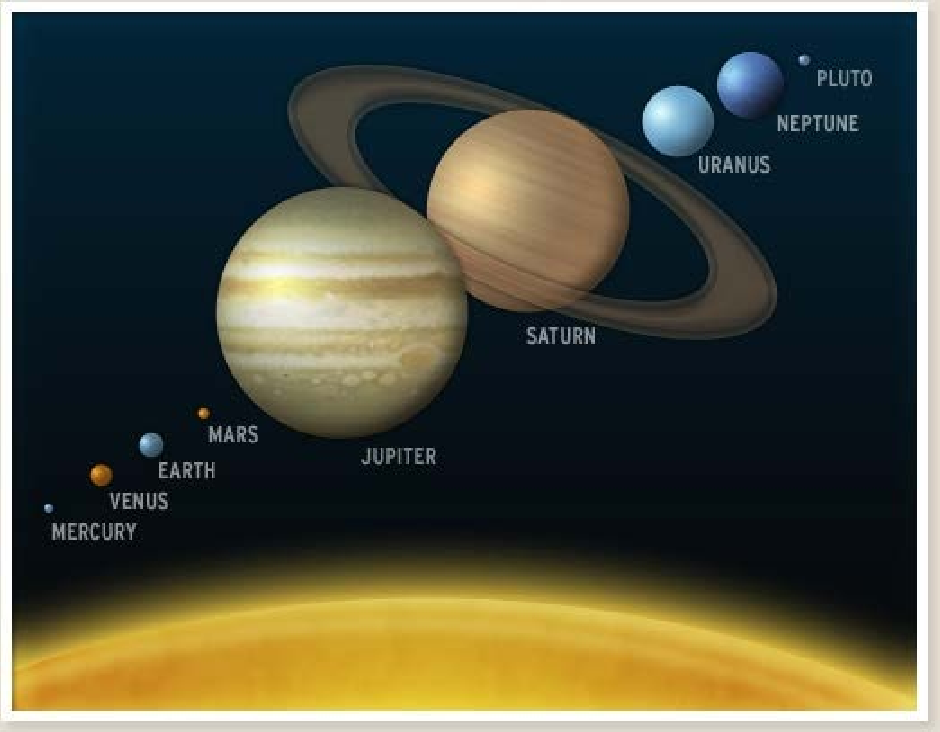
Flattened rotating nebula



Planetesimal hypothesis

Physical Properties of the Planets

- Size
- Density
- Distance from sun



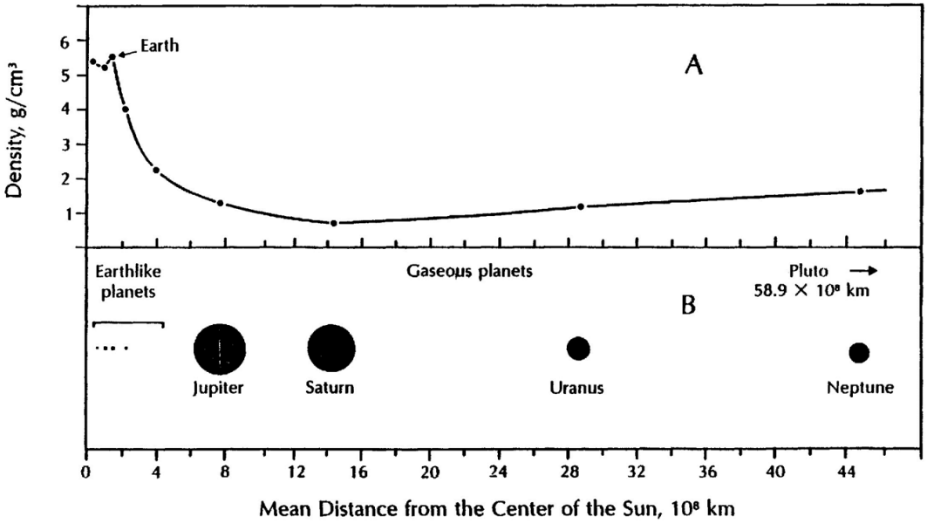


Figure 3.1 **A:** Variation of density of the planets with mean distance from the Sun. Note that the Earth has the highest density among the earthlike planets, which, as a group, are more dense than the outer gaseous planets. **B:** The planets of the solar system magnified 2000 times relative to the distance scale. The earthlike planets are very small in relation to the Sun and the gaseous planets of the solar system.

Chemistry of the Planets - Meteorites

Iron meteorite

Stony meteorite

Stony-iron meteorite

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Most meteorites come from the Asteroid belt

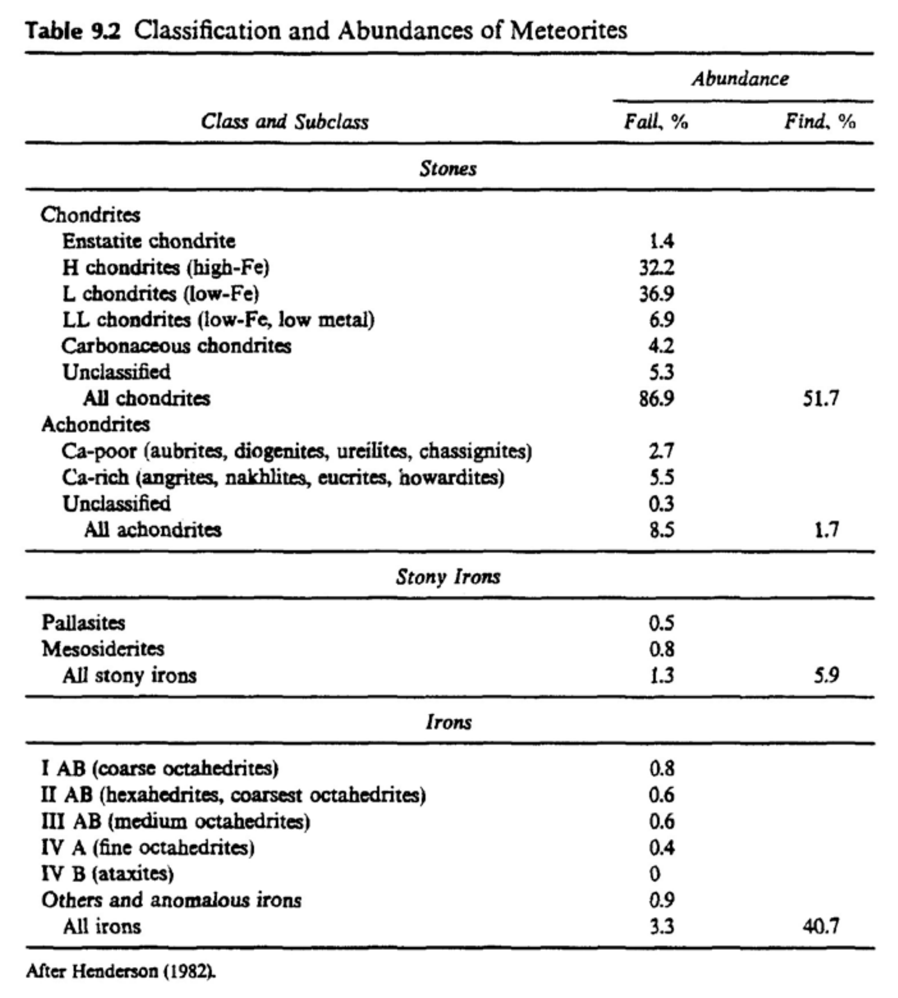

Table 9.2 Classification and Abundances of Meteorites

Class and Subclass	*Abundance* Fall, %	*Abundance* Find, %
Stones		
Chondrites		
Enstatite chondrite	1.4	
H chondrites (high-Fe)	32.2	
L chondrites (low-Fe)	36.9	
LL chondrites (low-Fe, low metal)	6.9	
Carbonaceous chondrites	4.2	
Unclassified	5.3	
All chondrites	86.9	51.7
Achondrites		
Ca-poor (aubrites, diogenites, ureilites, chassignites)	2.7	
Ca-rich (angrites, nakhlites, eucrites, howardites)	5.5	
Unclassified	0.3	
All achondrites	8.5	1.7
Stony Irons		
Pallasites	0.5	
Mesosiderites	0.8	
All stony irons	1.3	5.9
Irons		
I AB (coarse octahedrites)	0.8	
II AB (hexahedrites, coarsest octahedrites)	0.6	
III AB (medium octahedrites)	0.6	
IV A (fine octahedrites)	0.4	
IV B (ataxites)	0	
Others and anomalous irons	0.9	
All irons	3.3	40.7

After Henderson (1982).

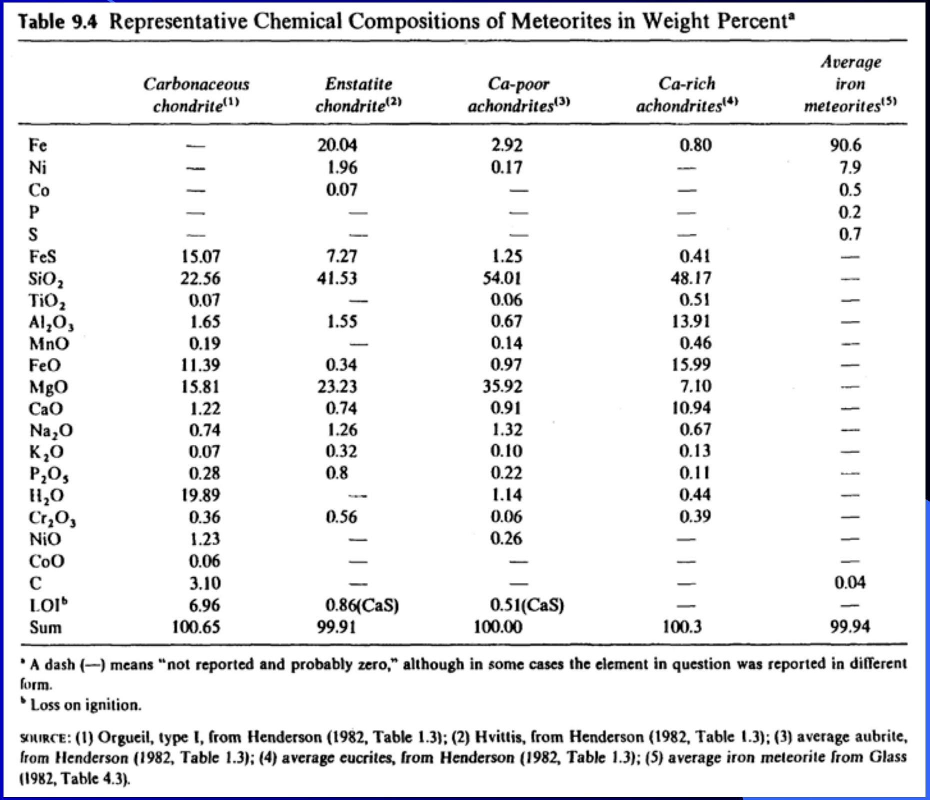

Table 9.4 Representative Chemical Compositions of Meteorites in Weight Percent[a]

	Carbonaceous chondrite(1)	*Enstatite chondrite*(2)	*Ca-poor achondrites*(3)	*Ca-rich achondrites*(4)	*Average iron meteorites*(5)
Fe	—	20.04	2.92	0.80	90.6
Ni	—	1.96	0.17	—	7.9
Co	—	0.07	—	—	0.5
P	—	—	—	—	0.2
S	—	—	—	—	0.7
FeS	15.07	7.27	1.25	0.41	—
SiO_2	22.56	41.53	54.01	48.17	—
TiO_2	0.07	—	0.06	0.51	—
Al_2O_3	1.65	1.55	0.67	13.91	—
MnO	0.19	—	0.14	0.46	—
FeO	11.39	0.34	0.97	15.99	—
MgO	15.81	23.23	35.92	7.10	—
CaO	1.22	0.74	0.91	10.94	—
Na_2O	0.74	1.26	1.32	0.67	—
K_2O	0.07	0.32	0.10	0.13	—
P_2O_5	0.28	0.8	0.22	0.11	—
H_2O	19.89	—	1.14	0.44	—
Cr_2O_3	0.36	0.56	0.06	0.39	—
NiO	1.23	—	0.26	—	—
CoO	0.06	—	—	—	—
C	3.10	—	—	—	0.04
LOI[b]	6.96	0.86(CaS)	0.51(CaS)	—	—
Sum	100.65	99.91	100.00	100.3	99.94

[a] A dash (—) means "not reported and probably zero," although in some cases the element in question was reported in different form.

[b] Loss on ignition.

SOURCE: (1) Orgueil, type I, from Henderson (1982, Table 1.3); (2) Hvittis, from Henderson (1982, Table 1.3); (3) average aubrite, from Henderson (1982, Table 1.3); (4) average eucrites, from Henderson (1982, Table 1.3); (5) average iron meteorite from Glass (1982, Table 4.3).